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The mean wind at 60 mb.

by

J. K. Bannon and R. A. Jones.
(Meteorological Office)

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Summary

An attempt is made to chart the mean wind over the world at the level of 60 mb. (20 km.) in the mid-season months January, April, July and October. Stream lines and isotachs are shown on Mercator charts for the latitudes 75°N. to 60°S. Mean vector resultants of observed winds at 60 mb. are tabulated; frequencies of wind directions are also listed for a few stations.

1. Introduction

The mean upper winds over the world at levels up to 100 mb. (approximately 54,000 ft.) have been described and mapped by Brooks and others (1) and more recently by Jenkinson (2). An attempt is made here to extend this work to the level of 60 mb. (approximately 65,000 ft. or 20 km.).

The mean flow for latitudes poleward of about 25° is represented by the contour lines of the height of the constant pressure surface. This is the method adopted in the previous studies and it is known (1,3) that the geostrophic winds measured from such charts are an adequate approximation to the true mean wind. Isotachs (lines of equal mean speed) are also drawn; the contour lines are equivalent to mean stream lines. For latitudes less than 25° the mean flow is also shown by isotachs and stream lines which were estimated directly from observed winds.

As data for levels above 100 mb. are few the charts can only give a rough outline of the true mean winds. The accuracy of the charts can be expected to be least over the tropics where observations are few and the geostrophic approximation cannot be invoked as an aid.

2. Wind summaries

Direct observations of wind at 60 mb. are few. Most of the observations are from radio-- or radar - wind soundings. A few pilot-balloon observations are available and there are also a few determinations of wind by acoustic methods. All the data are unfortunately liable to bias. The radio - or radar-winds are necessarily biased towards lighter winds at lower levels and so may not be truly representative of all conditions. This is particularly evident over North America during winter and spring where direct observations are fewer than at other seasons, strong westerly winds in the troposphere causing the balloons to drift out of range of the tracking instrument. Pilot-balloon observations are unlikely to be representative of all conditions; the limitations of this type of data are well known. Acoustic methods of measurement lack precision and the numbers of observations are very small.

/Table

Table I contains the station names, their geographic positions, the period covered by the observations and the type of observation (e.g. radar-wind).

Table II contains the mean vector resultant winds at 60 mb. for all stations at which ten or more observations are available during any one mid-season month. Resultants from less than ten observations are enclosed in brackets. The number of observations and the speed and direction of the maximum observed wind are also given.

Supplementary tables (Table III A, B) give the frequency of wind direction for the following groups of stations:-

A. British home stations and Ocean Weather Ships. British stations in the Mediterranean - Middle East region, together with Nairobi and Khartoum. Directions are in 30° intervals centred on the cardinal points.

B. Pacific island stations, Albrook Field and Havana, for the directions of a 16 point compass, centred on the cardinal points.

In the tables the observing stations are first grouped according to latitude, namely north of 60°N., 30° to 60°N., 10° to 30°N. in the Northern Hemisphere. In these separate zonal belts the stations are then arranged latitudinally from north to south in the broad areas America, British Isles area, Mediterranean and Middle East, Japanese Main Islands and Pacific. In the equatorial regions and the Southern Hemisphere two divisions only are used, namely, 10°N. to 10°S. and 10°S. to 60°S.

The form in which the data are available differs from station to station. In summarising and computing the vector resultants the following methods were used:-

(a) British home and overseas stations, Nairobi, Lagos, Khartoum, Hong Kong, Falkland Islands and Pacific island stations. Data were extracted in the form of frequency distributions of wind speed and direction for the 60 mb. surface. These frequencies were then compounded vectorially.

(b) American stations (excepting the acoustic results) and the Japanese Main Island stations. Data were already available in the form of monthly vector resultant winds at 20 km. These were compounded for the separate areas.

(c) New Zealand stations and Woomera. Values at 65,000 ft. were interpolated between the values at 60,000 and 70,000 ft. given in the original data. When there was a reversal of direction between the two heights both values are quoted.

3. Charts of the mean wind

The mean flow at the level of 60 mb. is shown by charts of stream lines and isotachs for each of the mid-season months January, April, July and October. (Figs. 1 to 4). The stream lines in temperate and high latitudes are taken as the mean contour lines of the height of the 60 mb. pressure surface.

These contours were constructed as follows: - Charts showing the mean temperatures at standard pressure levels up to 100 mb. are available in the Upper Air Climatology Branch and charts had been computed from these of the mean height of each of the standard pressure surfaces. These contour charts may not be accurate in detail since the method of computation assumed constant lapse rates of temperature between the standard levels. It is believed, however, that they are not much in error except perhaps over Siberia and in

/regions

regions of the Southern Hemisphere where observations are lacking. The above charts of the height of 100 mb. surface were the basis for the construction of the charts for 60 mb. Observations of temperatures in the layer 100 to 60 mb. are few. However, mean lapse rates were obtained for this layer from available data and mean lapse rates were inferred for all regions by interpolation and extrapolation from these. The thickness of the layer 100 to 60 mb. was evaluated from these lapse rates and the mean temperature distribution at 100 mb. This thickness was then added to the height of the 100 mb. surface to obtain the contours of the 60 mb. surface. A grid of points at intervals of 10° latitude and 20° longitude for latitudes polewards of 30° was used in constructing the mean thickness of the layer 100 to 60 mb. and in effecting the addition of this thickness to the 100 mb. chart. Some smoothing was necessary in drawing the final contours of the 60 mb. surface. These contours are given at intervals of 400 geopotential ft. Contour charts of the 100 and 50 mb. surfaces for North America prepared by the U.S. Air Weather Service (6) were consulted and were of assistance in drawing the 60 mb. contours in that region.

Since observations above the level of 100 mb. are so few, these contour charts for temperate latitudes cannot be considered accurate though it is hoped that they show the main features correctly. It should be noted that an error in estimating the lapse rate will have only a small effect on the computed value of the thickness 100 to 60 mb. The mean lapse rate between 100 and 60 mb. seems to vary little for a particular latitude belt for any one month; the greatest variation noted was 5°C. over the layer 100 to 60 mb. between Japan and the corresponding latitude in southern Europe in July. The variation is usually less than 2°C. An error of 2°C. in estimating the mean fall of temperature between 100 and 60 mb. will result in an error of 1°C. in the mean temperature of this layer leading to an error of only 50 ft. in the thickness of the layer. An error of 2°C. in the mean temperature at 100 mb. will result in an error of 100 ft. in the thickness of the layer 100 to 60 mb. The accuracy of the contours of the 60 mb. surface thus depends mainly on the accuracy of the contours of the 100 mb. surface and on the accuracy of the charts of mean temperature at 100 mb.; the latter are probably the less well determined.

The wind speeds from which the isotachs were constructed were mainly derived from the charts using the geostrophic relation. Direct observations were used in the few places for which they are available.

In the tropics the stream lines and isotachs were constructed from the wind observations. The principle that the mean flow must be largely without horizontal convergence or divergence was of assistance in the drawing; thus inflow into any particular region must roughly balance outflow. Nevertheless, even the main features of the flow in the tropics may not be adequately described in these charts because of the lack of observations.

The mean resultant winds given in Table II are also plotted on the charts. The number of observations is indicated at the head of the wind arrow. In temperate latitudes greater weight is given to the orientation and spacing of the mean contours than to the observed mean resultant winds.

4. Discussion of charts

(a) January (Fig. 1)

(i) Northern Hemisphere

The predominant feature of the mean flow in January is the general westerly circulation north of about 25°N. Two areas of maximum wind speed are shown, namely, over the Canadian Arctic and southern Greenland with speeds of 70 kt. and to north-east of Japan with speeds of over 90 kt.

/Over

Over the British Isles and the Mediterranean the mean winds are westerly of order 30 kt., but wind speeds of 70 kt. have been reported at most stations.

Darling (7), in an investigation of the mean flow at 50 mb. over the United States in 1952, shows the existence of a mean westerly flow of 25 kt. over the zone 31°N. to 40°N. and a pronounced westerly flow of 30 kt. over the zone 41°N. to 50°N.

The high velocity of 295°/150 kt. was recorded at Ocean Weather Ship V (31°N., 164°E.). Only two observations are available from this station in January, however, so it is impossible to judge whether such speeds are of regular or frequent occurrence.

South of about 20° to 30°N. the winds are generally light and variable. A few pilot-balloon observations over India at 60 mb. (8) show a westerly flow with a tendency to southerly components. The few wind observations at 65,000 ft. over Singapore (9) were moderate west-south-westerly.

Mironovitch (10), who has prepared a meridional cross-section at 150°E., indicates light easterly winds or calm south of 15°N. with westerlies north of this latitude with a maximum mean speed of 60 kt. at 60°N.

(ii) Southern Hemisphere

By analogy with the Northern Hemisphere in July it might be expected that the easterly flow south of the Equator would exceed 20 kt. over a considerable area. Mironovitch (10) shows speeds of 20 to 30 kt. in longitude 150°E. However, as there is no direct evidence of strong easterlies in this belt they are not shown in Fig.1.

Farkas (11) has recently summarised the observations of upper winds over Canton Island (02°49'S., 171°43'W.) for the period July, 1952 to June, 1953. This information became available after the charts in Figs. 1 to 4 were drawn. In the three months December, January, February, the mean wind at 20 km. (31 observations) was westerly, 12 kt., with a standard vector deviation of 22 kt. Palmer (12) states that a narrow belt of westerlies (what he calls "von Berson Westerlies") is probably to be found at heights from about 18 to 23 km. near the Equator at all seasons. The Canton Island observations and the few (less than 10) from Singapore are the only data known to the authors in support of the existence of this equatorial westerly stream in January. In Figs. 1 to 4 no attempt has been made to chart this westerly flow which is light where it can be found and seems to cover a small area.

The mean flow between 50° and 60°S. appears to be moderate westerly in contrast to the light and variable flow in similar latitudes in the Northern Hemisphere in July. This difference between the flows in the two hemispheres may not be the result of significant differences between the summer stratospheres of the two hemispheres but may be caused by the stronger westerly flow in the troposphere in the Southern Hemisphere in summer.

A wind with an easterly component has never been recorded over the Falkland Islands (52°S., 58°W.) at 60 mb.

/(b)

(b) April (Fig. 2)

(i) Northern Hemisphere

There are two main regimes, the westerly flow north of about 25°N. and the weaker and more variable flow south of 25°N.

The westerly stream is everywhere much weaker than in January and its southernmost limit has moved northwards slightly, the easterly winds having increased in frequency in the south.

The increase in the frequency of easterly wind from January to April in northern temperate latitudes is confirmed by Darling (7) who also shows that the mean flow over the zone 41°N. to 50°N. over America at 50 mb. in April, 1952 was westerly of the order of 10 kt.

In the westerlies mean winds are light or moderate but winds of 70 kt. have been observed over the Japanese Main Islands. The maximum wind reported was again at Ocean Weather Ship V in the Pacific where a wind of 270°/100 kt. was recorded, but the resultant wind for this station (based on 41 observations) is only 270°/10 kt.

At 100 mb. the mean contour map for April shows strong winds in many areas and there is also a strong meridional gradient of temperature at 100 mb. As stated in section 3 the method of obtaining the contours of the 60 mb. surface must necessarily give results that are inaccurate in detail, but since this method correctly indicates the weak flow in April, though computed from strong gradients at lower levels, one may confidently expect that the technique will reproduce the main features of the upper flow in temperate latitudes in other months.

Singapore (1°N., 104°E.) (9) and Batavia (6°S., 107°E.) (13) show south-westerly winds at 60 mb. but few observations are available. (The latter observations were by pilot-balloon, six in number, and therefore may not be representative.) Palmer (12, 14) shows that westerlies also occur in a narrow band near the Equator in the central Pacific in April (see reference to Canton Island below).

(ii) Southern Hemisphere

The mean flow is light variable or easterly from 0° to 25°S. The mean wind at Canton Island (11) in March to May, 1953, was south-easterly, 3 kt., (62 observations) with a standard vector deviation of 26 kt. The "von Berson Westerlies" were thus not apparent over that station at that time. As in January the belt of easterlies may contain stronger mean winds than are indicated.

South of 30°S. the mean flow is westerly and increases in strength poleward at least as far as 55°S.

(c) July (Fig. 3)

(i) Northern Hemisphere

North of about 40°N. mean winds are generally light and vary in direction. South of 40°N. there is a mean easterly stream.

Darling (7) shows that the mean flow over America at 50 mb. in July, 1952 was 15 kt. from an easterly direction in latitudes 41° to 50°N.

/The

The main area of maximum wind speed greater than 50 kt. is associated with the large Asian land mass and lies along the belt of latitude 15° to 20°N. from Khartoum to Hong Kong. The maximum wind velocity observed was 90 kt. from east at Hong Kong (22°N., 114°E.*) and wind speeds of the order of 40 kt. occurred at most stations south of 40°N.

Mironovitch (10) indicates an easterly flow across the meridian of 150°E. in the tropics with a maximum mean speed of 50 kt. at 20°N.

In equatorial regions Nairobi shows easterly and westerly winds of equal frequency with a resultant calm; the maximum wind recorded there was 070°/66 kt. The few observations from Singapore (9) show south-west winds.

(ii) Southern Hemisphere

Between the Equator and 20°S. the flow is probably light and variable.

The mean flow is strong westerly south of about 25°S. increasing southwards to speeds of the order of 70 kt. at 50°S. The maximum wind reported was 270°/110 kt. over the Falkland Islands.

(d) October (Fig. 4)

(i) Northern Hemisphere

As in April the mean flow can be divided naturally into two broad regimes, an easterly flow in the 10°N. to 30°N. zone and a general westerly flow north of 30°N. Both streams are stronger than the corresponding streams in April.

The mean currents are of moderate strength but maximum individual wind speeds of the order of 50 kt. have been recorded over the British Isles and the Japanese Main Islands.

Darling (7) shows that over the U.S.A. in 1952 there was a mean westerly flow of 15 kt. over the region 41° to 50°N. at 50 mb. and a mean westerly flow of 10 to 15 kt. in the zone 31° to 40°N.

The directions of winds observed at 60 mb. over Nairobi are variable. Hay (9) reports a moderate south-westerly flow over Singapore. Palmer (14) says that at 40 mb. (22 km.) there is a light westerly flow between longitudes 150° and 160°E. in the zone 0° to 7°N. but in the observations summarised in Fig. 4 the "von Berson westerlies" are only locally defined at 60 mb. (see also below).

(ii) Southern Hemisphere

Between the Equator and 20°S. winds are probably light variable or easterly. The mean wind at Canton Island in the autumn of 1952 (11) was 263°/18 kt. (27 observations) with a standard vector deviation of 18 kt. (see above). Over Nandi (Fiji) (4) the mean wind changes from westerly at 60,000 ft. to easterly at 70,000 ft.

/Westerly

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* Few observations are available from this station for 60 mb.

Westerly flow exists south of 30°S. increasing in strength southwards to about 50 kt. at 50°S. A maximum wind of 270°/70 kt. was recorded over the Falkland Islands.

5. Variation from year to year

There is evidence that variations occur in the mean flow at 60 mb. from year to year. The largest variations noted occurred during the Northern Hemisphere winter and summer seasons.

Wind speeds in general showed no marked variation from year to year.

The year 1952 showed a more easterly character in winter and early spring over America and the Pacific Ocean and also at Aden, Lagos and Nairobi than did other years.

Winds appear to be less variable from year to year in the Southern Hemisphere but observations are also fewer. In particular, however, the Falkland Islands observations are remarkably persistent in magnitude and in direction; no wind with an easterly component was reported in any month of any year during the period 1948 to 1953.

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/19.

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(c) Hong Kong (Royal Observatory)
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Appendix

(i) Wind data

The chief sources of data of radio- or radar-winds employed are:

(a) Northern Hemisphere

1. MS. data for M.O. stations both at home and overseas. (18)
2. MS. data for Nairobi, Lagos, Khartoum and Hong Kong. (19)
3. Data for stations in Japanese Main Islands. (20)
4. Data for the Pacific islands stations received in microfilm by courtesy of the Chief of the United States Weather Bureau. (21)
5. Data for the U.S.A. (22)
6. Data for mean winds over zones 31°N.-40°N. and 41°N.-50°N. at 50 mb. over America. (7)
7. Data from Nemuro and Nagasaki. (23)

(b) Southern Hemisphere

1. MS. data for the Falkland Islands. (18)
2. New Zealand Technical Notes Nos. 92, 94. (4, 5)
3. Mean winds over Pretoria (26°S., 28°E.). (24, 25)
4. Observations at Sydney, N.S.W. (35)
5. Deduced mean winds over New Zealand. (36)
6. MS. data for Woomera (double theodolite observations on pilot-balloons). (19)

Where no radar wind data were available, use was made of:

(i) pilot balloon data
(ii) high altitude winds derived from acoustical propagation studies.

Pilot balloon observations are mainly for India and its neighbourhood (8) and for Batavia in Java. (13)

Acoustical propagation results were used for the American stations Canal Zone (9°N., 77°W.), Florida (28°N., 82°W.), Denver (40°N., 105°W.) and Wray (40°N., 102°W.). (26, 27, 28, 29)

(ii) Contour height data

1. Preliminary 100 mb. circumpolar charts north of 55°N., and Mercator charts for the region 70°N. to 50°S. (30)
2. Contour charts over North America (4 year mean values 1947-1951). (6)
3. Stream line and isotach charts given by Jenkinson. (2)

(iii) Temperature data

1. Average temperature charts over the world. (31)
2. MS. data of British home stations.
3. MS. data of British overseas stations and the Falkland Islands.
4. Temperature data for North America. (6)
5. Data for Eureka (80°N., 85°W.) in Canada. (32)
6. Data for Auckland, Norfolk Is. (28°S., 168°E.) and Hokitika. (33)
7. Data for Heard Is. and Macquarie Island. (34)

Table I Wind observing stations

R = Radio- or radar- wind
P = Pilot-balloon
A = Acoustic determination

Station	Position	Type	Period of available data
North of 60°N.			
Narssarssuak	61°N. 45°W.	R	July, 1941-January, 1942.
Lerwick	60°N. 1°W.	"	1948-April, 1953.
30°N.-60°N.			
America			
American Zone (1)	31°N.-40°N.	"	1952.
" " (2)	41°N.-50°N.	"	1952.
Spokane	48°N. 118°W.	"	1950-53.
Caribou	47°N. 68°W.	"	"
Bismark	47°N. 101°W.	"	"
St. Cloud	46°N. 94°W.	"	"
Rapid City	44°N. 103°W.	"	October, 1945-January, 1946; 1948-July, 1950.
Omaha (Nebr.)	41°N. 96°W.	"	July, 1938.
Wray (Col.)	40°N. 102°W.	A	July, 1950-April, 1951.
Denver	40°N. 105°W.	A	January, 1951.
Grand Junction	39°N. 109°W.	R	1950-53.
Washington	39°N. 77°W.	"	"
Nashville	36°N. 87°W.	"	"
Greenboro'	36°N. 80°W.	"	"
Oklahoma	35°N. 98°W.	"	"
Hatteras	35°N. 76°W.	"	"
Albuquerque	35°N. 107°W.	"	"
Santa Maria	35°N. 120°W.	"	"
Little Rock	35°N. 92°W.	"	"
Charleston	33°N. 80°W.	"	"
Big Spring	32°N. 101°W.	"	"
British Isles Area			
O.W.S. "I"	59°N. 19°W.	"	1951-52.
Stornoway	58°N. 6°W.	"	1951-April, 1953.
Leuchars	56°N. 3°W.	"	"
Aldergrove	55°N. 6°W.	"	"
Hemsby	53°N. 2°E.	"	"
O.W.S. "J"	53°N. 20°W.	"	1951-52.
Larkhill	51°N. 2°W.	"	1951-April, 1953.
Camborne	50°N. 5°W.	"	"
Mediterranean and Middle East			
Gibraltar	36°N. 5°W.	"	1948-April, 1953.
Malta	36°N. 14°E.	"	"
Nicosia	35°N. 33°E.	"	"
Habbaniya	33°N. 44°E.	"	"
Benina	32°N. 20°E.	"	"
Japan			
Nemuro	43°N. 146°E.	-	from isopleths of height.
Wajima	37°N. 137°E.	R	1951-53.
Tateno	36°N. 140°E.	"	"
Yonago	35°N. 133°E.	"	"
Shionomisaki	33°N. 136°E.	"	"

/Nagasaki

Station	Position	Type	Period of available data
Nagasaki	33°N. 130°E.	-	from isopleths of height.
Kagoshima	32°N. 131°E.	R	1951-53.
Pacific			
O.W.S. "N"	33°N. 135°W.	"	1951-52.
O.W.S. "V"	31°N. 164°E.	"	"
10°N.-30°N.			
America			
San Antonio	30°N. 98°W.	"	1950-53.
Burrwood	29°N. 89°W.	"	"
Florida	28°N. 82°W.	A	January, 1951.
Brownsville	26°N. 97°W.	R	1950-53.
Miami	26°N. 80°W.	"	"
Havana	23°N. 82°W.	"	1951.
San Juan	18°N. 66°W.	"	1950-53.
Arabia, Sudan			
Bahrain	26°N. 51°E.	"	1948-April, 1953.
Khartoum	16°N. 33°E.	"	April, 1953-January, 1954.
Aden	13°N. 45°E.	"	1948-April, 1953.
Pacific			
Midway Island	28°N. 177°W.	"	1951-52.
O.W.S. "U"	28°N. 145°W.	"	"
Okinawa	26°N. 127°E.	"	"
Iwo Jima	25°N. 141°E.	"	"
Marcus Island	24°N. 154°E.	"	1951-53.
Hong Kong	22°N. 114°E.	"	1951-52.
Lihue Kauai	22°N. 159°W.	"	"
Hilo	20°N. 155°W.	"	"
Wake Island	19°N. 167°E.	"	"
Johnston Island	17°N. 170°W.	"	July, 1951-1952.
Clark Field	15°N. 121°E.	"	1951-52.
Guam	14°N. 145°E.	"	"
Eniwetok	11°N. 162°E.	"	"
10°N.-10°S.			
Albrook Field	9°N. 80°W.	"	1951.
Canal Zone	9°N. 80°W.	A	January, 1950.
Kwajalein	9°N. 168°E.	R	1951-52.
Kusaie	5°N. 163°E.	"	1951-52.
Lagos	7°N. 3°E.	"	1952, 1953 (except July), January, 1954.
Nairobi	1°S. 37°E.	"	1948-April, 1953.
Singapore	1°N. 104°E.	"	October, 1950-July, 1952.
Batavia	6°S. 107°E.	P	1909-1917.
10°S.-60°S.			
Pretoria	26°S. 28°E.	R	April-September, 1952; October, 1952-March, 1953.
Nandi	18°S. 177°E.	"	October, 1945-July, 1952.
Woomera	31°S. 138°E.	P(double)	July, 1950-October, 1954.
Auckland	37°S. 175°E.	R	1943-1951.
Hokitika	43°S. 171°E.	"	October, 1944-1950.
Invercargill	46°S. 168°E.	"	July, 1951-October, 1952.
Falkland Is.	52°S. 58°W.	"	1948-April, 1953.

Table II

Vector mean winds at 60 mb. for mid-season months

Station	January				April				July				October			
	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind
North of 60°N.																
Narssarssuak	-	-	-		(260)	(20)	(3)		-	Calm	37		(285)	(10)	(8)	
Lerwick	270	25	25	270/70	280	15	57	270/50	-	Calm	94	120/15	265	15	78	270/50
30°-60°N.																
America																
American Zone (1)+	W.	25	41		W.	10	266		E.	20	598		W.	15	435	
American Zone (2)+	W.	30	42		Var.	10	163		E.	15	151		W.	15	168	
Spokane	-	-	-		-	-	-		-	-	-		295	5	39	
Caribou	-	-	-		250	5	13		-	-	-		-	-	-	
Bismark	-	-	-		300	5	10		-	-	-		-	-	-	
St. Cloud	-	-	-		-	Calm	27		-	-	-		300	10	18	
Rapid City	(180)	(15)	(1)		235	15	11		110	10	12		335	5	10	
Omaha	-	-	-		-	-	-		030	5	22		-	-	-	
Grand Junction	-	-	-		-	-	-		085	15	23		320	15	11	
Washington	-	-	-		270	10	24		080	15	42		250	10	20	
Nashville	-	-	-		-	-	-		080	15	53		-	-	-	
Greenboro'	-	-	-		-	-	-		085	15	31		265	20	10	
Oklahoma	-	-	-		-	-	-		080	20	33		275	5	26	
Hatteras	-	-	-		-	-	-		075	20	20		240	5	14	
Albuquerque	-	-	-		-	-	-		085	20	35		015	5	22	
Santa Maria	-	-	-		125	5	29		090	20	61		045	5	57	
Little Rock	-	-	-		-	-	-		085	20	26		-	-	-	
Charleston	-	-	-		-	-	-		085	20	44		190	5	23	
Big Spring	-	-	-		-	-	-		085	25	31		-	-	-	
British Isles Area																
O.W.S. 'I'	(275)	(35)	(7)	270/70	(210)	(10)	(5)	210/35	255	5	45	270/15	(235)	(15)	(8)	240/25
Stornoway	290	35	16	270/70	290	20	21	270/50	-	(Calm)	(7)	060/15	255	5	11	210/25
Leuchars	295	35	16	300/50	280	20	38	270/50	-	Calm	46	090/25	285	10	48	270/50
Aldergrove	(270)	(20)	(2)	300/25	280	20	52	270/50	-	Calm	30	090/15	265	10	23	270/25
Hemsby	295	35	10	300/70	290	15	57	360/50	-	Calm	75	090/25	305	10	39	300/25
O.W.S. 'J'	275	35	28	270/70	295	5	18	270/25	-	Calm	25	300/15	295	10	10	300/25
Larkhill	290	30	33	270/70	290	5	70	270/50	095	5	128	090/25	280	10	98	300/50
Camborne	(295)	(25)	(6)	300/50	275	10	27	270/35	-	Calm	34	120/25	270	10	34	270/25

+ Zonal mean winds Zone (1) 41-50°N; Zone (2) 31-40°N.

/Mediterranean -

Table II (Cont.)

Station	January				April				July				October			
	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind
Mediterranean - Middle East																
Gibraltar	295	15	73	270/50	265	10	93	270/35	100	5	91	270/35	285	5	97	090/50
Malta	275	25	33	270/50	270	15	54	240/50	145	5	66	210/35	270	10	80	240/35
Nicosia	265	45	13	270/70	270	15	62	270/50	135	10	69	180/50	245	15	67	270/50
Habbaniya	265	35	15	240/70	260	15	71	240/50	105	15	76	120/35	275	10	37	270/35
Benina	(270)	(30)	(5)	270/50	285	10	21	300/35	110	15	60	090/35	245	10	37	270/35
Japan - W. Pacific																
Nemuro ⊬	260	15	-		090	45	-		-	-	-		-	-	-	
Wajima	-	-	-		-	(Calm)	(3)	290/15	E.	35	11	090/35	(W)	(15)	(4)	280/30
Tateno	(SW.)	(35)	(3)	265/60	(W.)	(20)	(3)	275/30	E.	20	37	200/30	-	Calm	16	255/60
Yonago	-	-	-		(SW.)	(5)	(1)		-	Calm	13	070/40	-	Calm	14	270/50
Shionomisaki	(W.)	(50)	(1)		(W.)	(20)	(1)		E.	30	11	065/40	(085)	(10)	(9)	
Nagasaki ⊬	270	50	-		270	15	-		-	-	-		-	-	-	
Kagoshima	-	-	-		(NW.)	(20)	(1)		E.	25	13		(W.)	(35)	(2)	230/40
O.W.S. 'V'	(280)	(139)	(2)	290/150	270	10	41	270/100	(095)	(35)	(4)	110/50	300	5	25	270/50
O.W.S. 'N'	-	-	-		299	11	10	340/40	083	17	17	090/30	244	10	24	270/60
10°-30°N. America																
San Antonio	-	-	-		-	-	-		085	25	56		025	5	12	
Burrwood	-	-	-		-	-	-		080	25	45		065	10	29	
Brownsville	-	-	-		-	-	-		095	30	34		090	10	11	
Miami	-	-	-		-	-	-		080	35	23		100	15	10	
Havana	280	5	19	360/50	(090)	(10)	(5)	110/20	091	34	25	090/48	093	12	33	090/40
San Juan	280	5	33		100	5	33		080	35	37		085	15	53	
Arabia, Sudan																
Bahrain	(275)	(30)	(4)	270/50	255	5	31	270/35	090	45	71	090/50	-	Calm	44	090) 270) 25
Khartoum	260	5	14	240/35	275	5	11	270/25	075	50	17	090/50	100	15	20	090/35
Aden	-	Calm	30	270/25	250	5	49	090/35	090	50	30	090/70	075	10	45	090/50

⊬ Computed winds (23)

/Pacific

Table II (Cont.)

Station	January				April				July				October			
	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind	Direction (degrees)	Speed (kt.)	No. of obs.	Max. wind
Pacific																
Midway	124	2	27	130/30	313	6	60	360/34	090	25	100	090/56	071	3	74	270/24
Ship 'U'	-	-	-		292	14	22	250/44	090	19	26	090/46	004	7	13	315/48
Okinawa	-	-	-		286	9	15	270/34	087	25	23	110/56	260	7	29	250/96
Iwo Jima	-	-	-		280	5	10	090/20	(084)	(33)	(4)	090/50	-	(Calm)	(4)	250/20
Marcus Is.	-	(Calm)	(9)	090/20	(050)	(10)	(8)	040/20	(095)	(30)	(2)	095/30	100	15	13	080/35
Lihue Kauai	043	8	20	110/52	345	3	50	070/26	090	33	76	090/48	087	11	55	090/32
Hilo	348	6	39	330/38	296	3	63	315/40	092	36	96	090/58	090	16	96	110/32
Wake	160	4	32	135/22	082	10	77	180/118()	085	35	95	090/62	086	17	66	090/42
Johnston Is.	065	5	15	110/35	(280)	(10)	(8)	295/70	(095)	(25)	(8)	090/44	093	14	41	135/50
Guam	081	4	32	070/24	-	-	-		097	37	18	090/60	097	17	55	110/82
Clark Field	260	2	43	090/32	081	7	33	090/32	091	43	22	090/74	094	20	44	120/50
Eniwetok	-	-	-		-	-	-		093	41	42	090/70	102	16	14	110/58
10°N. - 10°S.																
Albrook Field	280	15	46	270/80	100	3	25	135/40	090	37	25	090/72	100	13	60	090/46
Kwajalein	-	-	-		279	3	20	170/16	-	-	-		095	22	35	090/50
Kusaie	-	-	-		274	9	19	250/38	-	-	-		086	23	50	070/60
Lagos	055	5	14	300/35	250	5	11	270/20	*(070)	(30)	(7)	090/35	075	15	30	090/60
Nairobi	085	10	53	090/70	-	Calm	31	090/50	-	Calm	49	070/66	275	5	65	090/35
10°S. - 60°S.																
Pretoria°	E.	20	64	090/40	-	-	-		Var.	15	30	110/35	-	-	-	
Nandi	095	15	192		(145	5	99		(245	5	112		(288	5	103	
					*(095	20	42		(-	Calm	41		*(080	5	39	
Woomera	*(280	12	24		*(287	11	20		*(267	18	24		*(273	6	17	
	(079	2	24		(211	1	20		(262	5	24		(086	15	17	
Auckland	*(270	5	79		*(285	20	55		(-	-	-		(-	Calm	150	
	(090	10	26		(335	5	31		(260	20	73		(090	15	43	
Hokitika	E.	5	-		W.	15	-		W.	15	-		W.	10	-	
Invercargill	*(290	10	11		280	20	36		270	35	58		*(270	10	73	
	(060	5	11		-	-	-		-	-	-		(-	Calm	41	
Falkland Is.	260	20	21	270/50	265	35	17	270/70	260	70	11	270/110	260	45	17	270/70

* The two values concerned are the mean wind at 60,000 ft. and 70,000 ft. respectively.
* 65,000 ft. wind for July at Lagos.

° Half-yearly mean resultant winds (24, 25)
() Next highest 225/52

Table IIIA

Frequency of wind direction at 60 mb.

	Station	30	60	90	120	150	180	210	240	270	300	330	360	Calm	No. of obs.
							January								
North of 60°N.															
	Lerwick							2	6	6	4	2	1	4	25
30°- 60°N.															
British Isles Area	O.W.S. 'I'								3	3	1				(7)
	Stornoway								1	8	3	2	2		16
	Leuchars								1	6	4	5			16
	Aldergrove								1		1				(2)
	Hemsby								1	4	3	2			10
	O.W.S. 'J'							4	5	11	5	3			28
	Larkhill								4	12	7	8		2	33
	Camborne								1	1	3	1			(6)
Mediterranean - Middle East	Gibraltar						1		1	17	25	13	5	11	73
	Malta								3	17	9	1		3	33
	Nicosia								3	9	1				13
	Habbaniya								3	10	2				15
	Benina								1	3	1				(5)
10°- 30°N.															
	Bahrain									3	1				(4)
	Khartoum					1		1	1	2		1	1	7	14
	Aden		2	1	1	2	1			3	2		3	15	30
10°N.-10°S.															
	Nairobi	1	9	11	8			2	5	6	3	1	1	9	53
South of 10°S.															
	Falkland Is.							3	6	8	2	2			21

/April

Table IIIA (Cont.)

	Station	30	60	90	120	150	180	210	240	270	300	330	360	Calm	No. of obs.
							April								
North of 60°N.															
	Lerwick					1		5	4	13	10	4	1	19	57
30°- 60°N.															
British Isles Area	O.W.S. 'I'					1		1		1				2	(5)
	Stornoway							2	1	5	7	3		3	21
	Leuchars							1	5	13	5	6		8	38
	Aldergrove								12	13	7	12		8	52
	Hemsby								8	12	6	12	4	15	57
	O.W.S. 'J'									3	3	1	1	10	18
	Larkhill	2	1	1	4	1		1	2	9	4	5	3	37	70
	Camborne					1		1	4	5	1	3	1	11	27
Mediterranean - Middle East	Gibraltar			1		1	1	3	18	31	19	2	1	16	93
	Malta						1	1	10	23	9	5	1	4	54
	Nicosia							1	14	14	13	4		16	62
	Habbaniya	1						7	17	17	6	3		20	71
	Benina								1	6	3	1		10	21
10°- 30°N.															
	Bahrain		3		1			2	4	4	1			16	31
	Khartoum			1		1				2			1	6	11
	Aden	1	1	12	3	2	2	3		3	3			19	49
10°N.-10°S.															
	Nairobi	1	1	6	4		1		2	5	3	4		4	31
South of 10°S.															
	Falkland Is.						1	1	7	6	2				17
							July								
North of 60°N.															
	Lerwick	4	1	3	7		2		1			1	2	73	94

/30°-60°N.

Table IIIA (Cont.)

	Station	30	60	90	120	150	180	210	240	270	300	330	360	Calm	No. of obs.
							July (Cont.)								
30°-60°N.															
British Isles Area	O.W.S. 'I'						1	1	4	6	2			31	45
	Stornoway		1							1				5	(7)
	Leuchars	2	1	2	1	1	1	1	1	2	1	1		32	46
	Aldergrove	1	1	2	2	2		1	1	1	1			18	30
	Hemsby		4	10	2				1	1	2	1		54	75
	O.W.S. 'J'	1								2	4	1		17	25
	Larkhill	3	3	15	6	2	1	2	3	2	2		2	87	128
	Camborne		3	2	2		1		1	1				24	34
Mediterranean - Middle East	Gibraltar	3	13	20	15	7	3	2	2	4	1	1	1	19	91
	Malta	1	2	9	10	7	4	8		2	1	2		20	66
	Nicosia		2	15	17	6	6	3	3	1	1			15	69
	Habbaniya	1	6	24	28	5	2	1						9	76
	Benina		3	18	28	3		1						7	60
10°-30°N.															
	Bahrain			68	3										71
	Khartoum		9	8											17
	Aden			27	2										29
10°N.-10°S.															
	Nairobi		4	10	3	3	2		10	10	2	2	1	5	49
South of 10°S.															
	Falkland Is.							1		10					11
							October								
North of 60°N.															
	Lerwick						1	10	20	19	15	3		10	78

/30°-60°N.

Table IIIA (Cont.)

	Station	30	60	90	120	150	180	210	240	270	300	330	360	Calm	No. of obs.
							October (Cont.)								
30°-60°N.															
British Isles Area	O.W.S. 'I'						1	2	3	1		1			(8)
	Stornoway							2	2		2	1		4	11
	Leuchars							1	6	11	13	5		12	48
	Aldergrove							3	5	4	4	1		6	23
	Hemsby	1			1				1	6	6	8	2	13	39
	O.W.S. 'J'								1	1	4	1		3	10
	Larkhill						1	4	15	26	18	11	2	21	98
	Camborne							2	6	3	6	2		15	34
Mediterranean - Middle East	Gibraltar	1	4	3		1		2	8	20	15	4	3	36	97
	Malta							4	17	23	12	4		20	80
	Nicosia	1					1	5	23	18	5	5		9	67
	Habbaniya		1	1	1	1		1	1	12	6	1		12	37
	Benina	1	1					1	4	12	2			16	37
10°- 30°N.															
	Bahrain		1	9		1		1	1	6	3			22	44
	Khartoum			8	5									7	20
	Aden	2	8	11	1								1	22	45
10°N.-10°S.															
	Nairobi	3	6	7	3	2	1	4	10	16	8	2	1	14	65
South of 10°S.															
	Falkland Is.							1	4	10	2				17

Table IIIB

Frequency of wind direction at 60 mb.

Directions - 16 point compass

	Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Calm	No. of obs.	Max. velocity	
										January										Dir.	Kt.
30°-60°N.																					
	O.W.S. 'V'												1	1					(2)	290	150
	O.W.S. 'N'										1	2	2			1		3	(9)	340	30
10°-30°N.																					
	Midway Is.			2	3	2	2	1	2			2	1	2	1	1		8	27	130	30
	O.W.S. 'U'												2	1	1	1	2		(7)	290	40
	Havana			1	1	1		1			1	3	3	2			1	5	19	360	50
	Lihue Kauai	4	1	3		2					1		1	1	1		1	5	20	110	52
	Hilo	2	2	2	1				1			1	4	2	3	3	4	14	39	330	38
	Wake Is.		2	1	2	3		4	5		2		2	1		1		9	32	135	22
	Johnston Is.					1										1	1	12	15	110	35
	Clark Fld.		1	1	2					1	1	3	5	2		1		26	43	090	32
	Guam		1	6	6	3	3	2			2	2		2	2	2	1		32	070	24
	Eniwetok																	2	(2)		
10°N.-10°S.																					
	Albrook Fld.	1	1	1	1		1	1	1	1	1	4	10	10	2	2	1	8	46	270	80
	Kwajalein	2									1					1	1	1	(6)	360	20
										April											
30°-60°N.																					
	O.W.S. 'V'	2	1							1	2	4	6	3	4	1		17	41	270	100
	O.W.S. 'N'	1					1					2	2	1		1	1	1	10	340	40
10°-30°N.																					
	Midway Is.	4	2		7	5	1	1			4	2	4	12	1	9	8		60	360	34
	O.W.S. 'U'	1										4	3	1	3	3	1	6	22	250	44

/Okinawa

Table IIIB (Cont.)

	Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Calm	No. of obs.	Max. velocity	
										April (Cont.)										Dir.	Kt.
10°-30°N.	Okinawa					1							6	2	1		1	4	15	270	34
	Havana			1	2		2											1	(6)	110	20
	Lihue Kauai	5		3	1		1				1		2	6	1	1	1	28	50	070	26
	Hilo	1	1	3	1	3	3	2		2	1		11	2	4	1	1	27	63	315	40
	Wake Is.	9	9	13	18	9	2		1	2	2	2		2	2	2	4		77	180	118
	Johnston Is.				1	1					1		1	2				2	(8)	295	70
	Clark Fld.	2	2	6	5	7		1			1	1		2	1	2	1	2	33	090	32
	Guam					1													(1)	-	-
	Eniwetok					1								1				9	11	290	10
10°N.-10°S.	Albrook Fld.				2	2	2					1	1		1	1	2	13	25	135	40
	Kwajalein					1			1	1			3	2	1	1		10	20	270	16
	Kusaie		1									2	7	4	2			3	19	250	38
										July											
30°-60°N.	O.W.S. 'V'			1	1	2													(4)	100	50
	O.W.S. 'N'		2	3	4	2	1		1						1			3	17	090	30
10°-30°N.	Midway Is.		1	20	54	23												2	100	090	56
	O.W.S. 'U'		3	7	6	4	2	1					1					2	26	090	46
	Okinawa		2	6	9	1	3											2	23	110	56
	Havana		1	2	17	5													25	090	48
	Lihue Kauai			10	60	5				1									76	090	48
	Hilo			9	65	22													96	090	58
	Wake Is.		2	30	54	9													95	090	62
	Johnston Is.			4	3	2													(9)	090	44
	Clark Fld.			3	14	4		1											22	090	74
	Guam			4	8	4	2												18	090	60

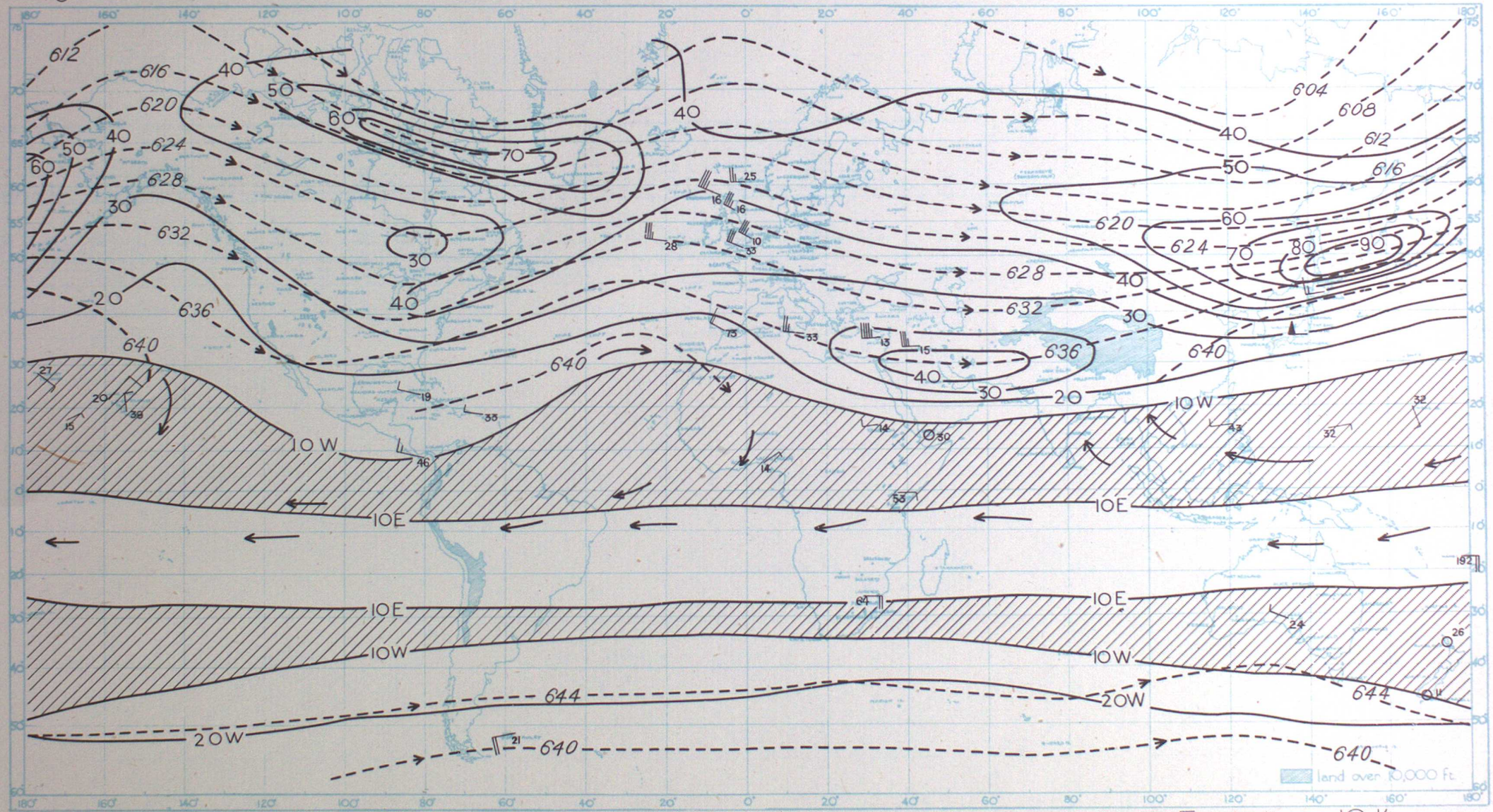
Table IIIB(Cont.)

	Station	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Calm	No. of obs.	Max. velocity	
									July (Cont.)											Dir.	Kt.
10°-30°N.																					
10°N.-10°S.	Eniwetok			3	31	6	1											1	42	090	70
	Albrook Fld.			2	14	6	1											1	24	090	72
	Kwajalein		1		1	1													(3)	050	30
									October												
30°-60°N.																					
	O.W.S. 'V'	2	1	3	1				2		1	1	2	2	1	1	1	7	25	270	50
	O.W.S. 'N'			1		1	1		1	2	1	4	3		2	2		8	24	270	60
10°-30°N.																					
	Midway Is.	3	5	8	5	6	1		2	1		1	2	2	3		1	34	74	270	24
	O.W.S. 'U'		1	1	1										1	1		8	13	315	48
	Okinawa			3	2	2	1		1	1	1	4	2	1		1		10	29	250	96
	Havana	1		4	13	2	2	1	1									9	33	090	40
	Lihue Kauai		3	6	17	5	2	2			3		1				2	14	55	090	32
	Hilo	1	5	17	33	22	2	1										15	96	110	32
	Wake Is.		4	17	23	12	3	1										6	66	090	42
	Johnston Is.		1	8	11	4	2											15	41	135	50
	Clark Fld.		1	4	25	7	1											6	44	120	50
	Guam		2	11	13	13	3	2	1					1			1	8	55	110	82
10°N.-10°S.	Eniwetok			3	4	3			1									3	14	110	58
	Albrook Fld.		2	7	14	8	3	2	1		1	1	2		1	1		17	60	090	46
	Kwajalein		2	2	14	8	2		1	1	1	1	2			1			35	090	50
	Kusaie	3	7	15	14	4	1											6	50	070	60

Fig.1

MEAN WIND FLOW AT 60 mb. JANUARY

M.R.P. 925



Streamlines (Contours of 60 mb. surface 100's of ft.)

Winds less than 10 Kt.

Isotachs (Kt.)

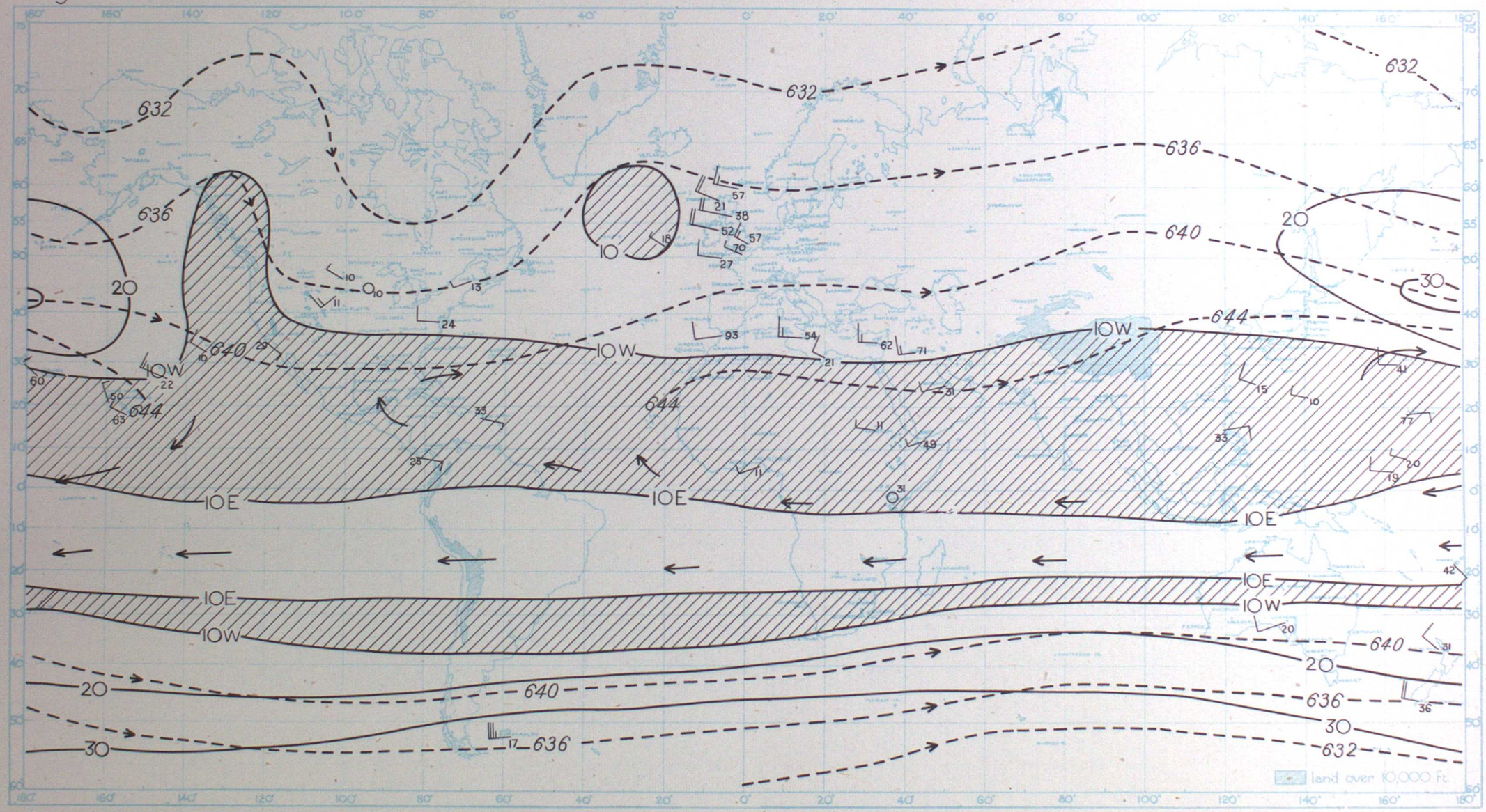
Streamlines in latitudes less than 30°

Mean wind observed Full feather = 10 Kt.
Triangle = 50 Kt. N° is number of observations

Fig. 2

MEAN WIND FLOW AT 60 mb. APRIL

M.R.P. 925



Streamlines (Contours of 60 mb. surface 100's of ft.)

Winds less than 10 Kt.

Isotachs (Kt.)

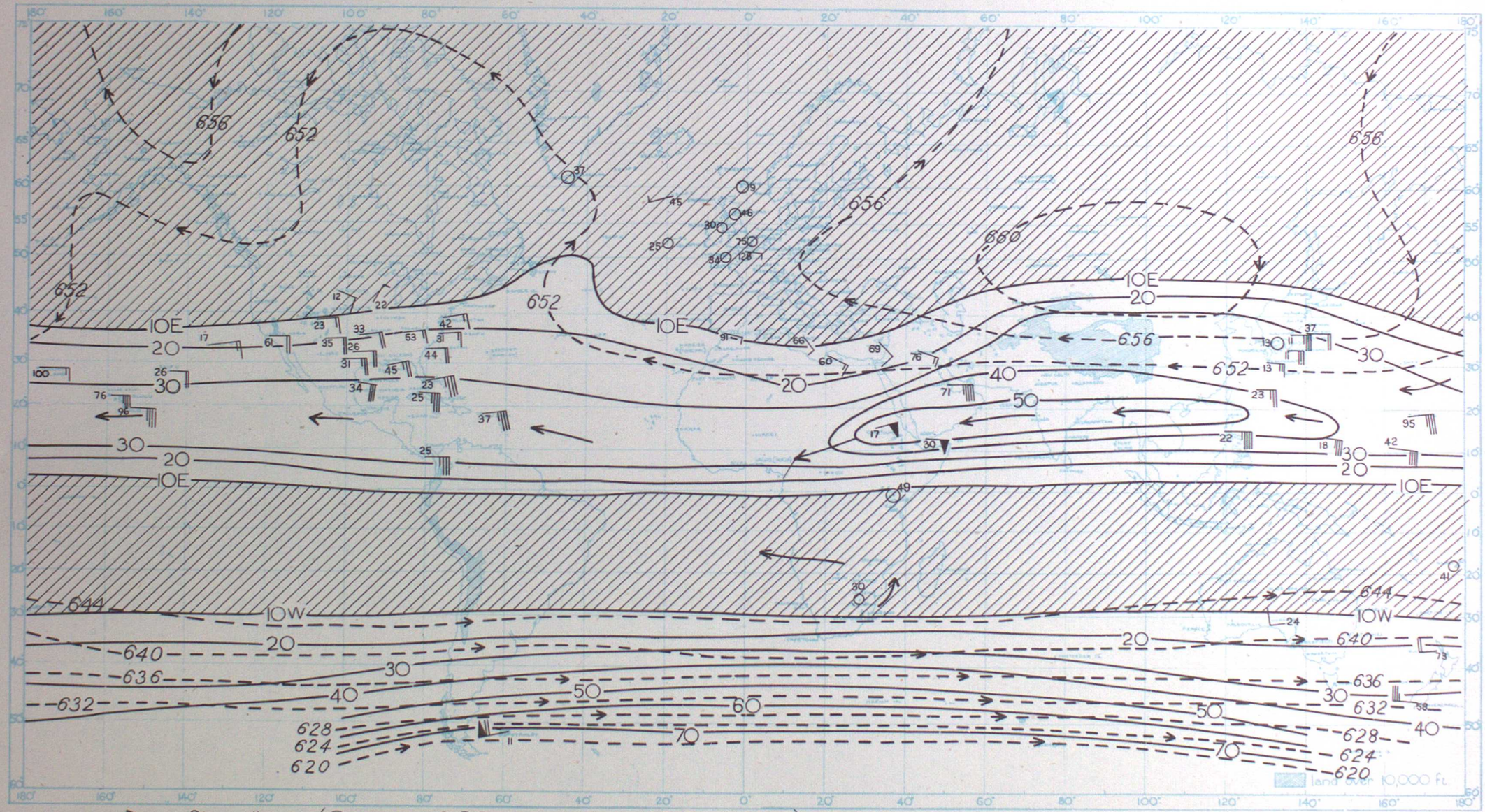
Streamlines in latitudes less than 30°

Mean wind observed Full feather = 10 Kt.
Triangle = 50 Kt. N° is number of observations

Fig. 3

MEAN WIND FLOW AT 60 mb. JULY

M.R.P. 925



Streamlines (Contour of 60 mb. surface 100's of ft.)

Winds less than 10 Kt.

Isotachs (Kt.)

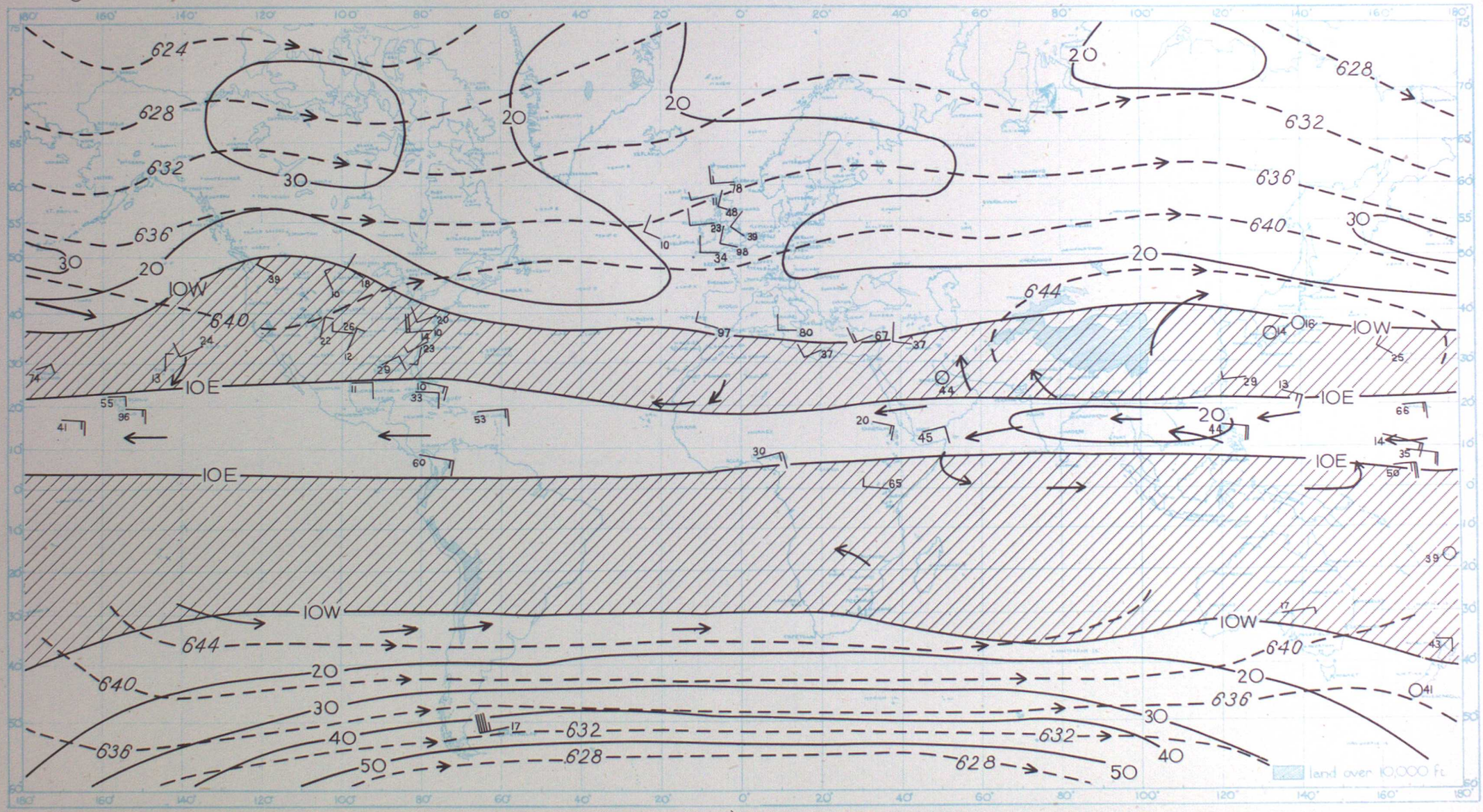
Streamlines in latitudes less than 30°

Mean wind observed Full feather = 10 Kt.
Triangle = 50 Kt. N° is number of observations

Fig. 4

MEAN WIND FLOW AT 60mb OCTOBER

M.R.P. 925



Streamlines (Contours of 60 mb. surface 100's of ft.)

Winds less than 10 Kt.

Isotachs (Kt.)

Streamlines in latitudes less than 30°

23 Mean wind observed. Full feather = 10 Kt.
Triangle = 50 Kt. Nº is number of observations